Energy and English wine production: A review of energy use and benchmarking

Energy for Sustainable Development 23 (2014) 85–91

Contents lists available at ScienceDirect

Energy for Sustainable Development

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Mervyn Smyth [a,*], Alistair Nesbitt [b]

[a] Centre for Sustainable Technologies (www.cst.ulster.ac.UK), School of the Built Environment, University of Ulster, Newtownabbey BT37 0QB, United Kingdom
[b] Plumpton College, Wine Department, Ditchling Road, Plumpton, East Sussex BN7 3AE, United Kingdom

ARTICLE INFO

Article history:
Received 23 December 2013
Revised 5 August 2014
Accepted 7 August 2014
Available online 29 August 2014

Keywords:
English wine production
Sustainability
Winemaking
Energy
Benchmark

ABSTRACT

The English (and Welsh) wine production industry, with more than 120 wineries, has many challenges linked to its northerly cool climate conditions and youthful status as a quality wine-producing country. The subject of sustainability remains important for producers, particularly as a means of improving the economic viability of wine production.

This paper presents energy usage within English winemaking facilities based upon energy audits conducted at an individual winery level. The survey did not include vineyard operations or energy usage. The wineries surveyed were representative of the geographic distribution of producers in England and included a range of production scales from a few thousand bottles per year to over 300,000 bottles per year. The combined (average yearly) bottle production for the wineries surveyed was 1,032,194 bottles, representing almost 26% of the total wine production capacity in England and Wales, expending 512,350 kWh of energy. Almost 44% of the energy expended in English wine production is related to heating, cooling and ventilation (HVAC) requirements, with 22% related to lighting. Extrapolating the study findings to the entire English winemaking industry (winery only) indicates that 2008 MWh of energy was expended in 2011. The average energy benchmark for English wine production is 0.557 kWh/l, ranging from 0.040 kWh/l to 2.065 kWh/l, which compares favourably with other wine producing regions.

The English wine industry

The English (including Welsh) wine production industry expanded rapidly from under 800 ha of established vineyards in 2005 to over 1300 ha in 2012 with more than 120 wineries, and it continues to grow. The wines produced are aimed at the premium market, with Sparkling Wines at the price-points occupied by good Champagne. Global warming, modern viticulture and oenology technology (growing grapes and making wine), and an improved skills base have all contributed to the growth of the industry in England. To maintain a sustainable industry, England must therefore address the grape and wine production challenges linked to its small size, northerly cool climate conditions and youthful status as a quality wine-producing country.

The challenges and thus experiences in producing quality wine in England have relevance to other emerging wine nations, even those in the developing world. India, for example, has been cultivating grapes for table use for centuries, but more recently, around 0.5% of the country's viticultural output has been turned over to wine production. Covering an area of approximately 3500 ha, primarily centred around one geographical region (Maharashtra), the majority of wine production is produced from small holdings of just 1 to 2.5 ha in size (Hinge, 2009). Given the relatively new status of Indian wine production, its organisation and infrastructure along with the challenges related to marginal climatic conditions there are many similarities with the UK wine industry. For many emerging nations/producers trying to establish themselves in the competitive global wine market, efficient production and improved economic viability are necessary. Energy sustainability is therefore seen as a key factor in reducing operating costs and achieving an overall sustainable business/industry model (Laurence Gould Partnership, 2012).

Energy use in English winemaking

There are many different systems, spaces and processes required in the modern winemaking facility. Fig. 1 schematically indicates some of the more common headings used to describe the activities associated with the production of wine. Each of these activities has a role within the modern winemaking facility and have a corresponding energy requirement, which collectively relates to an energy input necessary to produce the finished product. English wine is predominantly sparkling wine (currently ~50% of production) or light aromatic still wine wines. The shift over the last few years has been from growing older Germanic

* Corresponding author. Tel.: +44 2890 368119.
E-mail address: m.smyth1@ulster.ac.uk (M. Smyth).

http://dx.doi.org/10.1016/j.esd.2014.08.002
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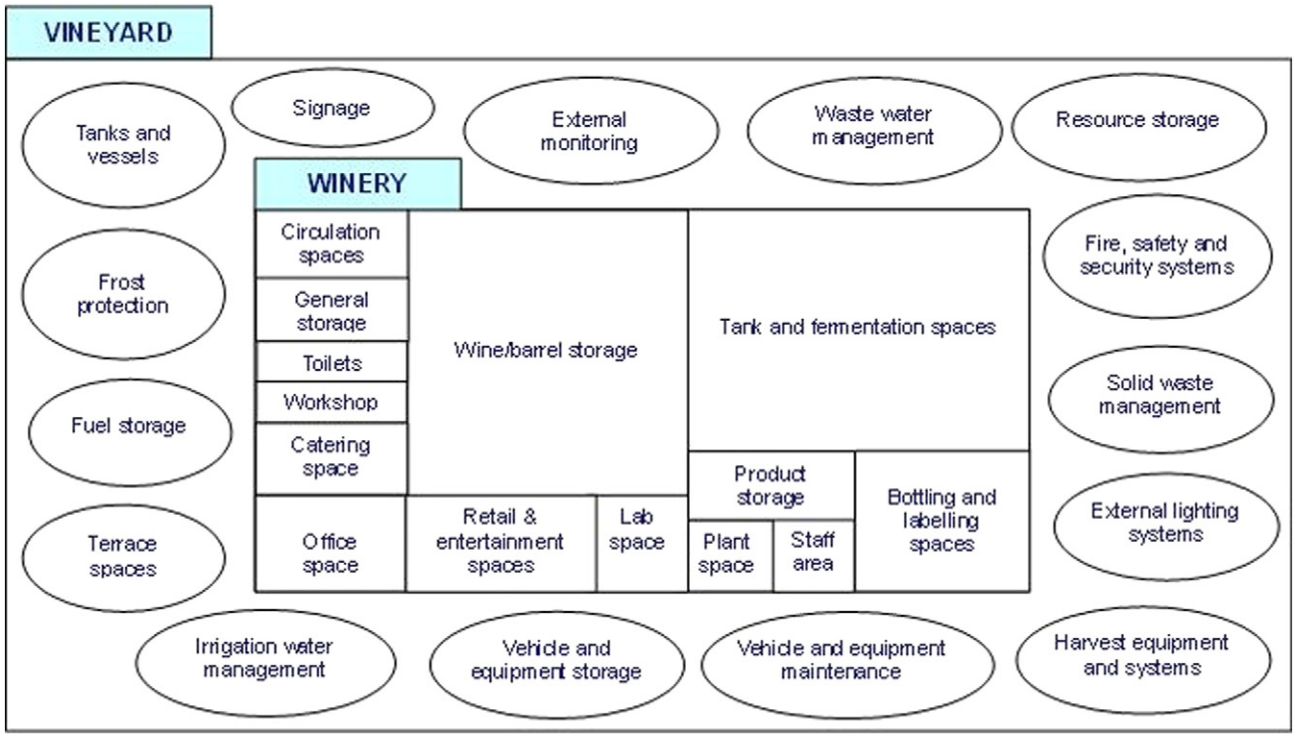

Fig. 1. Schematic representation of winemaking requirements (Smyth et al., 2011).

varietals to planting classic Champagne varieties: Pinot Noir, Pinot Meunier and Chardonnay to produce traditional method sparkling wine.

To accurately assess the absolute energy requirement of a commercial winemaking enterprise is quite a difficult task, due to the range and inter-relationship between variables, which includes highly variable parameters such as transportation to market or embodied energy. It is therefore more simplistic (and realistic) to determine the measurable indicators specific to each facility, namely the energy inputs that can be accounted for within the boundaries of the wine producing facility. This study did not quantify the total energy used from vine to bottle,

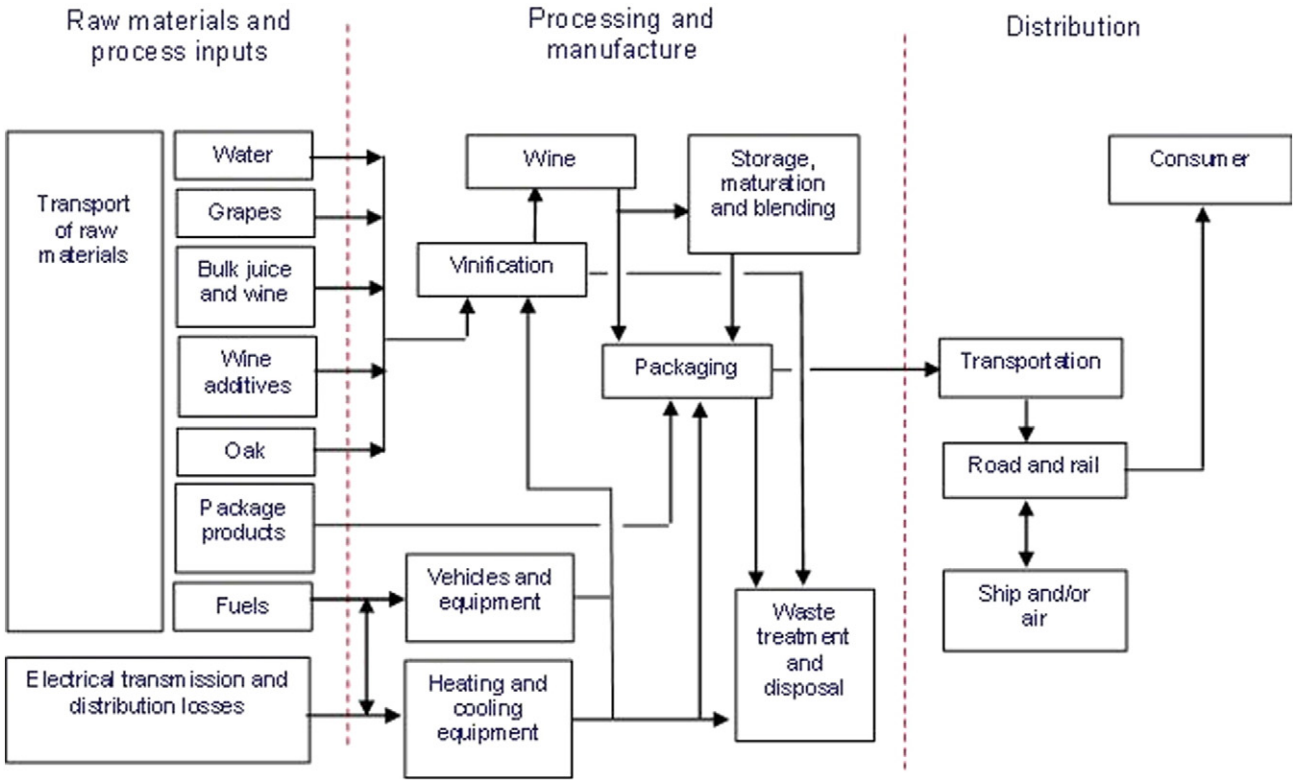

Fig. 2. Winery supply chain showing fuel and energy inputs (adapted from Forsyth et al., 2008).

but in other studies up to 50% of the energy consumed is from gasoline and diesel fuel used either in mobile agricultural equipment or road haulage vehicles.

To understand the process inputs and outputs that contribute to the energy use of a winemaking enterprise, one of the most effective methods is to map the supply chain so that all energy and fuel related inputs are accounted for. In simplistic terms this can be represented through the winery activities, as presented in Fig. 2.

English winemaking study

This study of energy usage within English winemaking facilities was conducted during the summer months of 2012. The energy study was based upon a representative number of energy audits conducted at an individual winery level including a walk-through energy survey (visual inspection and information relating to installed equipment and operating processes) of the winemaking facility and (where possible) at least 3 years historic production figures, end-use energy use and distribution. The survey did not include energy usage in vineyard operations. The wineries surveyed were representative of the geographic distribution of producers in England, with most existing in the South East and Southern England, and included a range of production scales from a few thousand bottles per year to over 300,000 bottles per year (at 0.75 l per bottle). Fig. 3 presents a geographical distribution of the wineries surveyed.

A total of 21 commercial wineries participated in the survey, representing 17% of the total 124 commercial wineries in England and Wales (English Wine Producers, 2012). Seventeen wineries from the 21 wineries surveyed, had full annual datasets relating to the energy used and corresponding production output values.

Energy use within the English wineries surveyed is described as either energy expended in wine production or energy expended in ancillary support services and relates directly to the end-use energy consumption. Energy used in production describes all the energy expended on the winery site by the processes and equipment necessary to produce the final product and covers everything from the arrival of the grapes at the winery door to the finished, packaged product leaving the facility. Ancillary support services relates to all the energy expended in the retail and administrative functions necessary to facilitate the winemaking process and includes wine tasting and sales, sanitation, food preparation, office and staff areas. The total winemaking energy use presented in this study is the combined value of energy expended in production and ancillary requirements for any given winery. This study did not cover the energy used in vineyard activities, product transportation, accommodation and other separate product processes conducted on the site such as beer, cider or cheese production.

In the English winemaking industry (Fig. 4), 62.9% of the energy used are supplied from a direct electrical supply (grid, photovoltaics, wind power, etc.). Gaseous and liquid based fossil fuels account for the remaining 37.1%.

From analysis of the surveyed English wineries, they tend to exhibit a slightly lower percentage of electrical power to liquid or gas sources compared to other global winemaking regions due to a number of factors. The main factor is the proportion of refrigeration and space heating required. The UK climate is colder than most other wine producing regions and therefore there is a greater demand for space heating (gas or oil input), primarily during the winter months but occasionally in the spring and autumn months. Likewise, the cooler ambient temperatures reduce the need for refrigeration (both comfort and winemaking processes), or at least the level of refrigeration required (electrical input). Due to the scattered, rural nature of many English vineyard/wineries, many wineries have either no direct electrical power supply or there is no 3 phase electrical supply available and therefore rely on an on-site (fossil fuelled) electrical generator to produce power. Even though the actual energy demand was electrical, a kWh ratio of typically 3:1 or 4:1 from the liquid fossil fuel calorific value was necessary to produce the electricity.

The vast majority of the energy used in the winery is related to production. From the information gathered from the commercial wineries participating in this the survey, 512,350 kWh of energy was expended to produce a total of 1,032,194 bottles of wine in an averaged year. Just over 431,226 kWh (or 84%) was used in production with the remaining 81,124 kWh related to ancillary support service requirements.

To enable an accurate representation of where energy was used with the winemaking facilities, an outline of energy categories was created. In this study production energy requirements were broadly categorised as being:

- Lighting: includes all energy associated with the lighting of the production/storage areas in the winery
- Grape processing: includes all equipment and processes involved in the receiving, crushing and pressing of grapes and any compressed air energy requirements

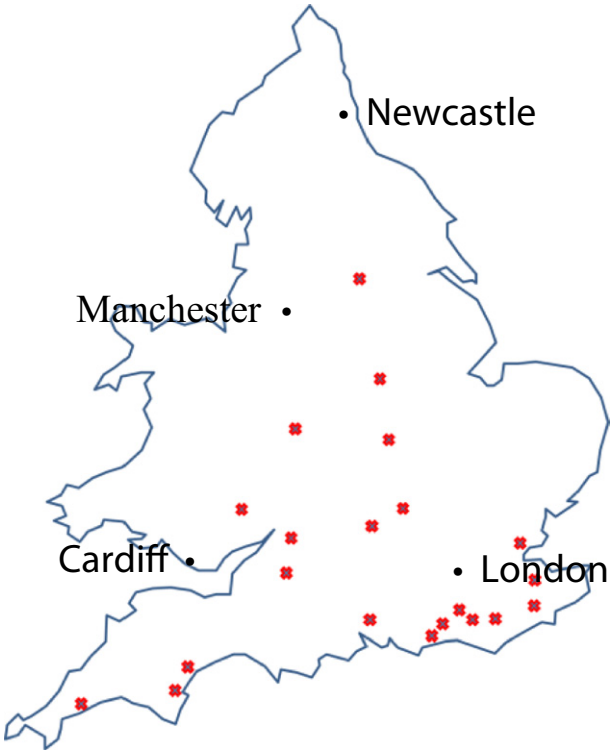

Fig. 3. Geographical distribution of the wineries surveyed in study.

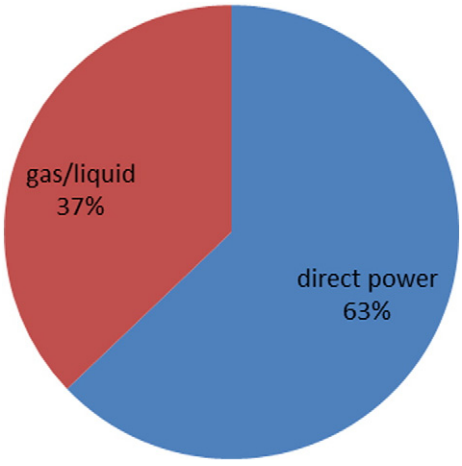

Fig. 4. Total annual energy supply breakdown in English wineries.

- Juice/wine pumping, filtration and mixing: includes all energy expended in the transfer of juice/wine from the press, tank to tank transfers, tank to bottling, filtration and mixing activities
- Bottling: includes wine filling, crown capping and disgorging, corking, wiring, foiling and labelling, packaging and compressed air energy requirements
- Thermal conditioning: includes all space and process heating, cooling and ventilation requirements, Low Temperature Hot Water (LTHW) and chilled water production and covers the energy used by refrigeration plant, Air Handling Units (AHUs), terminal units, fans and associated pumps and control devices
- Sterilisation and cleaning: includes equipment used in hot water and steam production, associated pumping and power washers
- Winery moving machinery: primarily fork trucks (gas, diesel, electric) but also includes electric trolleys and lifts
- Miscellaneous: a very broad category that includes a range of equipment necessary to provide a suitable working environment for the production processes and includes monitoring devices, security devices, shutter doors, insect control and laboratory equipment

Just over 57% of the surveyed wineries had separate administrative areas and dedicated wine tasting and retail areas open to the public. In this study, nearly 16% of the total annual energy used by the wineries was related to ancillary support service requirements. Ancillary support service energy requirements were broadly categorised as being:

- Lighting: includes all energy associated with the lighting of the retail, office and staff areas
- Thermal conditioning: includes all space heating, cooling and ventilation requirements
- Sterilisation and cleaning: includes all energy requirements used in sanitation activities
- Miscellaneous: a very broad category that includes PC, laptops and general office equipment (printers, fax machines, Wi-Fi and routers, telephones, laminators, shredders, photocopier), audio-visual equipment, cash registers, credit card readers, hand dryers, microwaves, bottle coolers and dishwashers.

Fig. 5 illustrates the bottle output from all winery activities. Based on the data collected from the study, the combined (average yearly) bottle production for the wineries surveyed was 1,032,194 bottles, equating to approximately 774,145 l of wine (both still and sparkling). Compared with the 2010 English harvest, which produced 3,034,600 l of wine, equating to just over 4 million bottles (English Wine Producers, 2011), this study represented almost 26% of the total wine production capacity. Previous studies have indicated that sparkling wine is the most widely produced wine style in England (English Wine Producers, 2011), representing approximately 50% of total production. This is broadly in line with the current study which identified 502,478 bottles (or 49%) to be sparkling wine and 529,716 bottles (or 51%) were still wine, collectively produced from five wineries which were exclusively sparkling wine production, 9 wineries which produced both sparking and still wine and 7 which produced still wine only. Nearly 37% of all the bottles produced came from a sparkling only producer, 60.6% came from a mixed sparking/still producer and only 2.4% came from a producer that produced still wine only.

The English wine industry is not a homogenous industry. This study highlighted the disparity between the various wineries and winemaking facilities and practices currently being used. All the wineries visited were more or less rural in a location which in itself led to interesting issues relating to utility connection (power, gas and sanitation), often resulting in a stand-alone operation. Just on size, there was a wide variation; the largest winery producing on average 313,771 bottles per year to the smallest producing just 1500 bottles in the same time period. All the wineries surveyed operated commercially, but could be broadly classified as being either small cottage concerns, family run businesses or large commercial companies. Due to the recent surge in English winemaking, a number of the wineries were relatively new, being in production for perhaps a few years. Likewise, an equal number of wineries had a long established name in the industry. Many wineries offered other parallel services by providing accommodation or having a restaurant or cafe or producing other products such as beer, cider or cheese. In addition to the wide range of wine produced by individual wineries, several wineries offered contract services to some of the smaller or less specialist wineries, in particular sparkling wine production services.

There was a wide distribution in the winery building types and range of equipment used within the various wineries. Most wineries were housed within one building, although almost a quarter of the wineries surveyed consisted of a number of separate buildings, scattered over the production area. A number of wineries were new purpose built, state-of-the-art winery buildings, designed with winemaking practices to the fore, including dedicated wine storage cellars or grape receiving stations. However, many of the wineries visited were created by refurbishing existing buildings (primarily farm buildings) or adapting existing spaces. Likewise, the level (and age) of equipment and process automation differed significantly, from fully automated winemaking facilities (with little human intervention apart from the moving of wine/bottles from station to station) to the more common partially automated or manual with significant mechanical input through to some wineries that were entirely manual in operation.

Fig. 6 illustrates the bottle output and annual energy consumption from all winery activities. Based on the data collected from the study, the combined (average yearly) bottle production for the wineries surveyed was 1,032,194 bottles, equating to approximately 774,145 l of wine.

A total of 512,350 kWh of energy was expended to produce a total of 1,032,194 bottles of wine in an averaged year from the surveyed

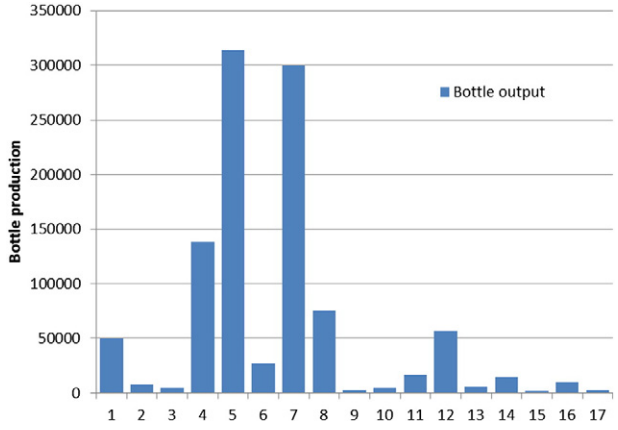

Fig. 5. Combined (average yearly) bottle production for the wineries surveyed.

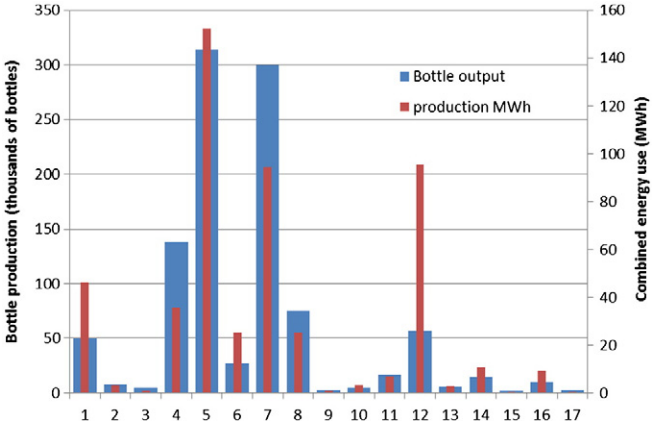

Fig. 6. Bottle output versus total energy expended by 17 English wineries.

wineries, of which 431,226 kWh (just over 84%) was necessary for production. As expected, there is a big variation from winery to winery, with some wineries requiring significantly more energy in relation to the production output. The reasons for the variety are many but are primarily dependent on the equipment or processes used, the winery size and style of wine produced.

Fig. 7 illustrates the distribution of energy expended in the production activities in all the English wineries investigated. Heating, cooling and ventilation are by far the biggest segment (44%) of energy use within the winery and therefore represent an area where the greatest energy savings could be made. The vast majority of this activity is made up from water chilling operations by a relatively small amount of large winemaking facilities. Bottling activities (8% for bottling equipment only and 13% including compressed air and disgorging equipment) reflect the use of significant mechanical power via the automated bottling machinery or lines, some refrigeration in the disgorging process and the generally inefficient use of compressed air systems. Lighting, at 22%, is the second largest area of energy usage with the winery. This is primarily due to the extensive use of inefficient lighting systems being used for prolonged periods of operation. Again, lighting represents an area which should be targeted to yield improvements in energy performance. Fork trucks and sterilisation/cleaning activities require a similar level of energy input.

In relative terms, grape processing and pumping (and associated activities) are very small segments of energy use within the winery. They are often the most visible activities of any winery and are certainly synonymous with the winemaking process. From a power requirement, much of the equipment may be the largest in the winery but from a usage of time, it can be one of the smallest. For example, a Coquard PAI8000 sparkling wine press using a hydraulic ram and gentle horizontal movement to break the press cake has a power rating of 10 kW. However, based on a typical 3 hour press cycle, the entire unit only uses 3 kWh of energy (Coquard Presses, 2012) (Fig. 8).

Winery size (or rather production output) has a significant impact on energy usage. In this study 5 wineries were categorised as large (greater than 50,000 bottles), 5 wineries as medium (10,000 to 50,000 bottles) and 7 wineries as small (less than 10,000 bottles). Fig. 9 illustrates the distribution of energy expended in the production activities in all the English wineries by production output.

On average, small wineries expend about 0.352 kWh/l on all winery activities due to lower levels of mechanisation. Medium wineries have the highest specific energy consumption at 0.975 kWh/l whilst large wineries due to economies of scale have a lower value of 0.510 kWh/l. The lower energy requirement for heating, cooling and ventilation is also evident as the winery reduces in size, from 0.168 kWh/l to 0.090 kWh/l (48% to 25%). Sterilisation activities are significantly higher in medium wineries compared to the other groups. The proportion of

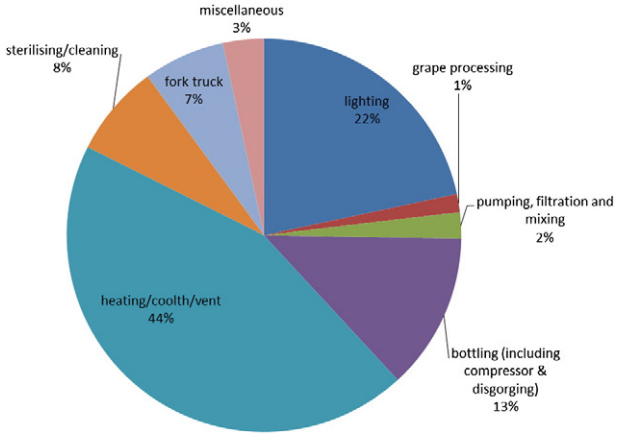

Fig. 7. Distribution of energy expended in production for all the English wineries investigated.

Fig. 8. Grape processing equipment representing a high power rating but relatively low energy usage.

other activities is seen to increase for small wineries (lighting, grape processing and miscellaneous). No small wineries had the capital to invest in dedicated fork trucks.

The style of wine produced by a winery has also a large impact on the energy use and Fig. 10 presents some interesting patterns. In this study 4 wineries were sparkling only, 8 wineries were mixed sparkling and still and 5 wineries were still only. Wineries that produced sparkling wine only required 1.181 kWh/l, mixed sparkling and still production expended 0.184 kWh/l and still production only was 0.423 kWh/l. Sterilisation and bottling activities (due to the greater number of individual processes) are significantly greater in sparkling only wineries. Heating, cooling and ventilation requirements are similar for sparkling and mixed sparkling/still production facilities due to the need for more refrigeration. Still wine production facilities in proportion therefore use more energy in lighting, grape processing and pumping activities.

Extrapolating the energy measured and reported in this study versus production output, the total annual energy expended by the English wine industry in making wine (in the winery) can be estimated. From the surveyed wineries, 512,350 kWh of energy was expended to produce a total of 1,032,194 bottles of wine in an averaged year, equating to approximately 774,145 l of wine. Compared with the 2010 harvest, which produced 3,034,600 l of wine, equating to just over 4 million bottles (English Wine Producers, 2011), 3,034,600 l would equal 2,008,380 kWh or 2008 MWh, which is equivalent to the energy released by burning 1181 barrels of crude oil (based on a barrel of oil equivalent (BOE)). In very rough terms, this is equal to the annual energy use of 200 households in the UK per year (based on an approximate

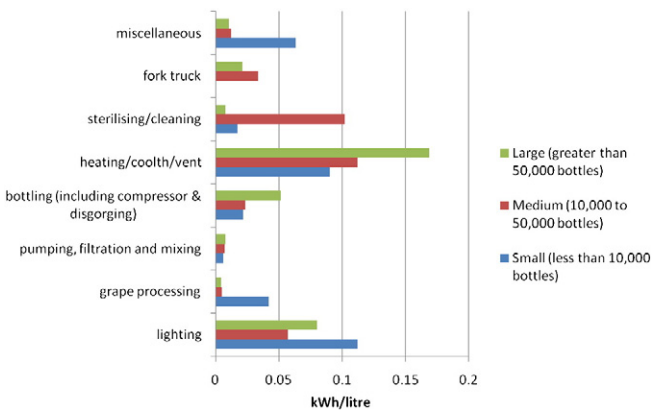

Fig. 9. Distribution of energy expended in production for large, medium and small English wineries (large (greater than 50,000 bottles); medium (10,000 to 50,000 bottles); small (less than 10,000 bottles)).

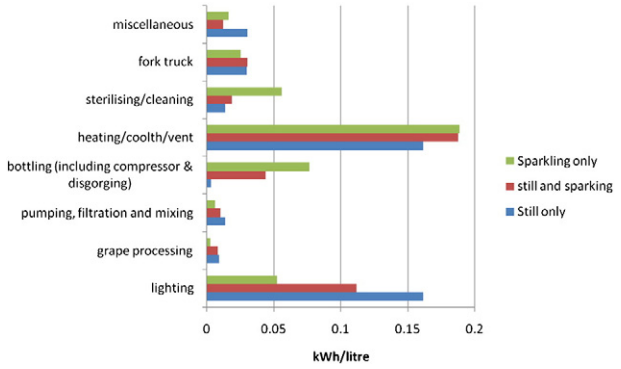

Fig. 10. Distribution of energy expended in production by wine style (sparkling only, mixed sparkling and still, still only).

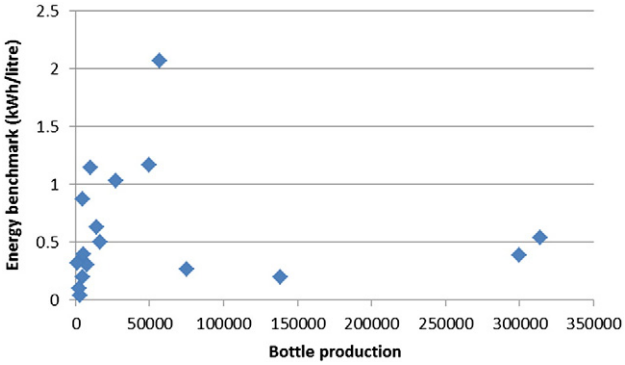

Fig. 12. Bottle output versus winery energy benchmark value (kWh/l) for 17 English wineries.

10 MWh thermal and electric per household) or based on the total primary energy consumption for the UK in 2010, 0.0000008% of the national demand (IEA, 2011).

Energy benchmarking of English wine production

Energy benchmarking, done properly, is a tool that allows the winery management to evaluate and compare their systems, processes and plant against the accepted benchmark values, providing a means whereby the winery can analyse their own energy consumption trends and patterns and instigate or follow improvements in energy usage.

Fig. 11 presents a range of kWh/l benchmark for production only from individual English wineries. What is apparent is that the individual benchmark values differ depending upon many variables; location, winery age, wine style and quality, facility size and production output. The average production benchmark is 0.557 kWh/l, ranging from 0.040 kWh/l to 2.065 kWh/l. As expected, the increased energy requirement in making sparkling wine is reflected in the benchmark values. Of the wineries surveyed that were exclusive sparkling wine producers, the calculated production benchmark was 0.86 kWh/l, and this dropped to 0.57 kWh/l for mixed sparking/still production and down to 0.42 kWh/l for still only production. Fig. 12 indicates the specific energy usage for winery operations versus bottle production. Given the size of the study, it is difficult to discern any obvious trends, particularly as the production size increases.

The benchmark value is equally variable when the total energy requirement is investigated. The average total benchmark is 0.662 kWh/l, ranging from 0.098 kWh/l to 2.239 kWh/l. The additional energy attributed to the retail and administrative requirements is only 0.105 kWh/l. Considering specific energy usage per floor area (kWh/m^2) for winery operations versus bottle production a more representative correlation develops (Fig. 13). As demonstrated in Fig. 7, HVAC and lighting energy use accounts for approximately two thirds of all the energy used in the winery space. This is not totally unexpected, as both HVAC and lighting systems are designed with significant reference to the space floor area.

To date, there are very few studies that have quantified the regional or national energy used in the production of wine. However, a number of studies do exist from which a comparison for the English benchmark metrics can be compared (Table 1). The New Zealand wine industry has embraced sustainable winemaking, with individual wineries such as the Mission winery using less than 0.2 kWh per litre of wine produced. The Mission Winery is the lowest wine industry energy user in New Zealand. The average New Zealand energy benchmark was calculated at 0.47 kWh/l (Van der Zijpp, 2008), whilst a Canadian study gave a range from 0.21 to 1.9 kWh/l (Anon, 2006) and the Australian energy benchmark ranged from 0.75 to 2.0 kWh/l (Anon, 2010). A study of the South Australian wine industry presented an average of 2.14 kWh/l (Anon, 2010). In Western Australia the Ferngrove winery used 0.25 kWh/l of wine. The sparkling wine producer, Domain Carneros in California had a calculated benchmark of 1.62 kWh/l (Smyth, 2010).

Nova Scotia's wine industry is a small yet growing wine industry. At the very northern climatic limits of wine production, the industry profile has many parallels with the English wine industry. In 2006, 130 hectares of grape vines in 30 wineries produced nearly 700,000 l of 'Nova Scotia wine', primarily sparkling and white still wines from hybrid varietals. In a study investigating the life cycle environmental impacts of wine production and consumption in Nova Scotia (Point, 2008), a value of 0.52 kWh/bottle (0.38 kWh/bottle from electricity and 0.02 l/bottle of heating oil) was determined for the industry as a whole, equating to nearly 0.7 kWh/l.

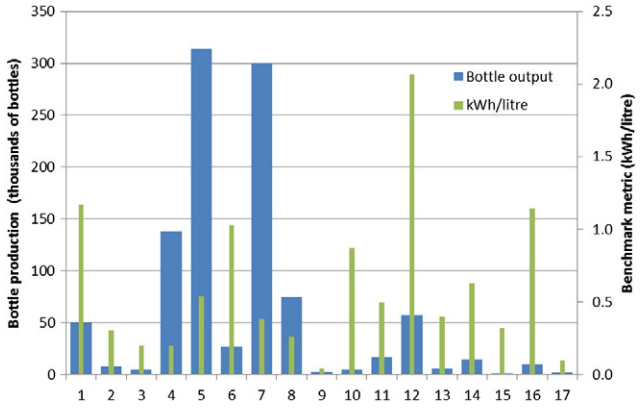

Fig. 11. Bottle output versus specific energy value (kWh/l) for 17 English wineries.

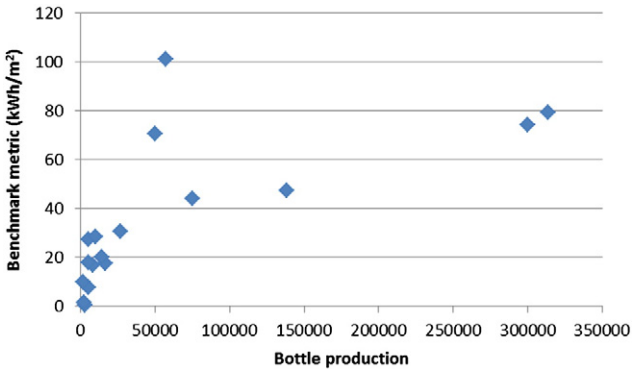

Fig. 13. Bottle output versus winery energy benchmark value (kWh/m^2) for 17 English wineries.

Table 1
Various regional/national energy benchmark metrics.

	kWh/l
New Zealand average	0.47
The Mission winery, NZ	0.2
Canadian range	0.21 to 1.9
Nova Scotia average	0.7
Australian range	0.75 to 2.0
South Australian average	2.14
Ferngrove winery, WA	0.25
Domain Carneros, California	1.62
English average	0.557 kWh/l

Conclusion

The English wine industry is not a homogenous industry. Like the buildings and production processes, there is considerable disparity between the various wineries and winemaking facilities and their associated energy usage. Winery size and style of wine produced have a comprehensible impact on the amount of energy used. Generally, smaller bottle production and winemaking facility relates to a lower energy requirement. Increasing production tends to relate to greater mechanisation and servicing without necessarily leading to economies of scale. Only with the larger, commercial facilities does the specific energy used tend to decrease again. Similarly, sparkling wine production tends to be more energy intensive whilst still wine production exhibits much lower values. On balance, when comparing the total measured/calculated metrics of English wine, the average production benchmark of 0.557 kWh/l is significantly lower than many of the other global wine regions that currently have data available. However, there are many wineries worldwide that have demonstrated that much lower values can be attained and thus there is still a substantial reduction in energy usage potentially achievable within the English winemaking industry.

This study highlights that heating, cooling and ventilation (at 0.25 kWh/l of wine produced) and lighting (0.12 kWh/l wine produced) are the largest end-use energy requirements where the greatest energy savings can be made. This said however, it is important to appreciate that any winery is a dynamic environment and therefore one area cannot be considered in isolation. Broadly speaking, good energy management represents the main area where easy yet significant savings can be realised. Good monitoring, record keeping, observation and communication are integral to this process. Taking lighting as an example, many wineries had no management or control of their lighting installations which quite often could be fully on for prolonged periods, even when not needed. By simply managing the lighting requirement when and where it was required would yield immediate savings. Another area of concern was the use of old, inefficient components, equipment and systems being applied in the wrong application or inappropriately sized for the given task.

Whilst the surveys conducted highlighted many examples of poor practise, there were equally many examples of good practise. Unwanted external heat gains are not a significant all year round problem for most English wineries, but from time to time, extremes in summer-time day temperatures, coupled with direct/indirect solar gain, can lead to overheating in the internal winery environment (something that is expected to increase with global warming). Whilst rising ambient temperatures could be seen as initially positive for English viticulture, higher temperatures will mean more refrigeration for production/storage activities and HVAC services, increasing the overall energy demand. One winery used deciduous trees to reduce winery overheating; during full leaf, the trees provided shade but during the winter when the leaves had fallen off, the sun was able to shine through, providing some additional solar gain and daylight. A couple of other wineries removed the need for refrigerant cooling of their fermentation tanks by the use of evaporative cooling or mains water cooling via an integral heat exchanger to control tank temperatures. In evaporative tank cooling a capillary material such as hessian cloth was draped over the tank and a small amount of water applied to the material. As the water evaporates into the surrounding air, the phase change activity extracts heat from the tank underneath, thereby providing a limited level of uncontrolled cooling. Mains water cooling was achieved by providing a trickle flow of water (at ground supply temperatures) through an integrated tank heat exchanger.

As the English (and Welsh) wine production industry continues to grow, it must establish itself in the competitive global wine market through efficient production and improved economic viability. Energy sustainability is therefore seen as a key factor in reducing operating costs and achieving an overall sustainable business/industry model. Understanding the current status of energy usage within the industry is the first step in creating a sustainable industry that will be prepared for future challenges. It is interesting to note that as better grape growing conditions are realised in England by higher ambient temperatures, due to global warming, there may be a move away from sparkling wine production to more recognised 'vinifera' still wine production. As the energy involved in still wine production is shown to be considerably less than sparkling wine production, the average benchmark value may be seen to reduce or at least counteract the rise in specific energy benchmark that tends to follow the development of an emerging 'cottage' winemaking industry into a modern, commercial industry. This paper presents an overview of the first extensive energy study to investigate and quantify the energy used in English wine production, creating a national energy benchmark for the industry. The full study can be found in the online report—Energy and English Wine Production (A review of energy use, benchmarking and good practice) (Smyth and Nesbitt, 2013).

References

Anon. Developing energy benchmarks for the Ontario wine industry. Ontario, Canada: Altech and Ontario Centre for Environmental Technology Advancement; 2006.

Anon. Winery energy management project: Cape Mentelle Audit. Perth, Australia: Grape and Wine Research and Development Corporation; 2010.

Coquard Presses. Personal correspondence with Jean Pierre Masset. France: Coquard Presses; 2012.

English Wine Producers. UK vineyards celebrate record breaking production figures. Press Release: 4th May 2011. London, UK: The English Wine Producers Trade & Press; 2011.

English Wine Producers. English wine production statistics (Information supplied by Wine Standards Branch (Food Standards Agency)). London, UK: The English Wine Producers Trade & Press; 2012.

Forsyth J, Oemcke D, Michael P. Greenhouse gas accounting protocol for the international wine industry: version 1.1. South Australia: Provisor Pty Ltd, Hartley Grove, Urrbrae; 2008.

Hinge RB. A study on diffusion and adoption of wine grape production technology in Maharashtra [Doctorial thesis] Dharwad, India: College of Agriculture, Dharwad University of Agricultural Sciences; 2009.

IEA. International Energy Agency World Energy Statistics 2011 edition released on 05 September 2011; 2011. http://dx.doi.org/10.5257/iea/wes/2011.

Laurence Gould Partnership. Greening UK wine—a sustainability policy for the UK wine industry. PO Box 284, Cirencester, England: United Kingdom Vineyards Association; 2012.

Point EV. Life cycle environmental impacts of wine production and consumption in Nova Scotia, Canada. Canada: Master of Environmental Studies, Dalhousie University, Halifax, Nova Scotia; 2008.

Smyth M. Solar energy in the winemaking industry. Global Research Report, Award Ref: 10177/177. London, UK: The Royal Academy of Engineering; 2010.

Smyth M, Nesbitt A. Energy and English wine production (a review of energy use, benchmarking and good practice). http://www.wineskills.co.uk/sustainability, 2013.

Smyth M, Russell J, Milanowski T. Solar energy in the winemaking industry (green energy and technology). 1st ed. Springer; 2011 [ISBN-10: 0857298437, ISBN-13: 978-0857298430].

Van der Zijpp S. Improving energy use in the wine industry. Membership pack, Sustainable Winegrowing New Zealand, PO Box 845, Blenheim 7240, New Zealand; 2008.